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INQUIRY TRAINING AND PROBLEM SOLVING IN ELEMENTARY SCHOOL CHILDREN.

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THE EFFECT OF PLANNED GUIDANCE ON THE PROBLEM-SOLVING BEHAVIOR OF ELEMENTARY STUDENTS WAS INVESTIGATED. FACTORS RELATED TO CHANGES IN PROBLEM-SOLVING BEHAVIORS WERE IDENTIFIED. APPROXIMATELY 50 PERCENT OF THE SIXTH-GRADE STUDENTS INCLUDED IN THE STUDY WERE GIVEN INQUIRY TRAINING 30 TO 60 MINUTES DAILY FOR 3 WEEKS. AN INVENTORY OF SCIENCE PROCESSES WAS CONSTRUCTED FOR THE STUDY. QUESTIONS INCLUDED IN THE INSTRUMENT WERE STUDIED BY A PANEL OF SCIENCE EDUCATORS AND ANALYZED FOR VALIDITY AND RELIABILITY. STUDENTS WERE PRE-TESTED AND POST-TESTED FOR KNOWLEDGE OF SCIENCE AND ABILITY TO USE THE PROCESSES RELATED TO PROBLEM-SOLVING IN SCIENCE. OTHER DATA WERE OBTAINED FROM STUDENT RECORDS. THERE WAS A SIGNIFICANT RELATIONSHIP BETWEEN INQUIRY TRAINING AND CHANGES IN THE PROBLEM-SOLVING BEHAVIORS OF STUDENTS, BUT NO SIGNIFICANT RELATIONSHIP BETWEEN INQUIRY TRAINING AND CONCEPT TRANSFER OR CHANGES IN RECALL OF FACTUAL KNOWLEDGE. OTHER ANALYSES INDICATED NO RELATIONSHIP BETWEEN MEASURED INTELLIGENCE, CHRONOLOGICAL AGE, SCIENCE FACTUAL KNOWLEDGE, OR SEX AND CHANGES IN PROBLEM-SOLVING BEHAVIORS THAT OCCUR IN CONJUNCTION WITH INQUIRY TRAINING. THIS ARTICLE IS PUBLISHED IN THE "JOURNAL OF RESEARCH IN SCIENCE TEACHING," VOLUME 4, ISSUE 1, 1966. (AG)

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An experiment designed to determine whether children can benefit from directed instruction in the strategies of problem solving.

Inquiry Training and Problem Solving in Elementary School Children

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The Problem

The education of an individual includes his becoming familiar with usable concepts in addition to his knowing how to solve problems using these concepts.

Generalized concepts emerge from specific data collected by the learner through some experience. These data are first organized into percepts and then, hopefully, internalized by the individual into broad conceptual schemes. However, a concept is not merely the merging of percepts, for as Butts indicated,

> ... it is a dynamic part of the cognitive structure that helps direct the attention of a student in a new situation; it helps organize the new perceptions into new meaningful configurations or new concepts.[1]

This dynamic quality that concept formation shares with the problem-solving experiences, was described by Garone in the following:

> Concepts represent the ultimate essence of past experience, and provide the embryonic structure for present and future experiences ... they are *organizations of experiences*, individualized networks of mental configurations[2]

If a concept includes both information and the way that information is organized, how can children be taught the way, the approach, or the search necessary for organizing this information? Does concept formation fit into problem-solving experiences?

Complete agreement on the feasibility of teaching all children to solve problems does not exist. For example, Ausubel suggested that

> ... the ability to solve problems calls for qualities less generously distributed in the population of learners than the ability to comprehend verbally presented material. As a result, relatively few good problem solvers can be trained in comparison with the number of persons who can acquire a meaningful grasp of various subject matter fields.[3]

The study reported here was designed to seek more information related to the preceding hypothesis by studying the following questions:

1. Do elementary school children, if they are exposed to guidance which is designed to help them enhance their problem-solving behaviors, show behavior patterns that are indicative of more effectiveness in problem solving?

2. Are such factors as a child's tested intelligence, sex, chronological age, or factual knowledge of science related to the change or lack of change in his problem-solving behavior patterns that occur in conjunction with instruction that is designed to help him find more effective ways to solve problems?

3. Do elementary school children, if exposed to guidance which is designed to help them enhance their problem-solving behaviors, show behavior patterns that are indicative of meaningful concept development?

The Procedure

Sample

The subjects of this study were 109 sixth grade students in the Highland Park Ele-

mentary School in the Austin (Texas) Independent School District. As taken from their school records, using the most recent score, the tested intelligence of the subjects ranged from 89 to 157, with 120 being the median. In pretesting, as measured by the *Sequential Test of Educational Progress* (STEP), science knowledge scores ranged from 242 to 297 out of a possible score of 311. The median score was 273. As measured by the National Achievement Test, *Elementary Science Test*, science knowledge scores ranged from 0.57 to 0.95 with a median of 0.85. The range in chronological age was from 130 to 160 months with 143 months as the median age.

Experimental Design

Approximately one-half of the subjects (classes A and B) were involved in the planned guidance which was designed to help them enhance their problem-solving behaviors. The other two classes (C and D) served as a control group. For those who were involved in the guidance, these steps were followed: (*1*) pretest; (*2*) planned guidance; (*3*) post-test. The second step (guidance) was omitted for the control group.

a. Testing

Before the guidance period, all students involved in the study received a battery of three tests:

1. *Sequential Test of Educational Progress* (STEP), Form A;

2. National Achievement Test *Elementary Science Test*, Form A;

3. The *Tab Inventory of Science Processes* (TISP).

Of the two forms of TISP, Form A was given to control class C and also to class A. Form B was given to control class D and to class B.

After the planned guidance period, all of the students were administered tests similar to those they received in the pretesting period. Form B of both the STEP and *Elementary Science Test* were given. Also administered were the two forms of the TISP; each class was given the form which they had not taken in the pretesting period.

b. Planned Guidance

The guidance program used in this study was based on that devised by Suchman as inquiry training.[4] In this method, the child is presented a problem in the form of a physics problem–focus film and after seeing the brief filmed demonstration, he is asked "Why?". It is then up to him to solve the problem. If the child wishes to gather information, he is instructed to ask questions that are answerable by a "yes" or "no" response. By gathering data through his inquiry questions and by assimilating his thoughts, the child is expected to solve the problem. From this and subsequent problems, it is anticipated that the child will conceptualize.

The possibility exists that after a number of such problem situations, in which the child is given ample opportunity to solve problems and to conceptualize, he will develop specific habits that may help him in future problem situations.

The inquiry training period had at least three broad objectives:

1. To develop the cognitive skills of searching and data processing and the concepts of logic and causality that would enable the individual child to inquire autonomously and productively;

2. To give the child a new approach to learning by which he could build concepts through the analysis of concrete episodes and the discovery of relationships between variables;

3. To capitalize on the intrinsic sources of motivation: the rewarding experiences of discovery and the excitement that is inherent in autonomous searching and data processing.[5]

Inquiry training sessions were held five days a week for three weeks. The periods of inquiry ranged from 30 to 60 min. Once the students had learned the procedures of

operation, the following sequence of events was followed:

1. A critique was made of the preceding session;

2. A problem episode film was shown (as many times as the children requested);

3. The students asked questions.

Testing Instruments

Design of Instruments

The instrument developed for this study was the *Tab Inventory of Science Processes* (TISP). This test used the tab format as described by Glaser, Damrin, and Gardiner[6] and Butts.[7]

It has been asserted that when a child inquires into a problem situation, he (*1*) searches, (*2*) processes data, (*3*) discovers, (*4*) verifies, and (*5*) applies conceptual understandings to new situations. To sample these behaviors, TISP is designed to include at least one of the above activities into five categorical sections. These sections are:

I. The child is presented with a hypothetical situation and is asked to predict what will happen.

II. A similar problem situation is presented in the form of a physics problem-focus film. The child is then asked to describe in his own words why the apparatus in the film behaved as it did.

These first two sections give an indication of the child's predictive behaviors and his ability to explain. It also gives some indication of his past background in science. Thus, in these sections the child has the opportunity to search and process data.

III. The child is presented with a list of questions that he might want to ask in order to gather data. Each of these questions can be answered by a "yes" or "no" response. If the child cares to ask a question, he pulls the numbered tab corresponding to that question and reads the answer under the tab.

In Section III the child has an opportunity to search for clues either by asking about the properties of part of the apparatus used in the experiment or by finding the results of hypothetical experimental questions. Thus the child in this section of the inventory has an opportunity to search and verify.

Each of the questions in Section III was studied by a panel of four science educators at The University of Texas, in addition to the investigators, for (*1*) accuracy of the statement and (*2*) type of question. In determining the type of question, the twenty-three questions on each form were placed in one of eight categories. These categories are:

1. Data-Gathering Questions.

A-1. Irrelevant questions—material unrelated to the solution of the problem.

B-1. Inadequate questions—information which, if taken by itself, is inadequate for the solution of the problem.

C-1. Additional information—extra information which is really not necessary for a highly proficient problem solver who could probably infer this.

D-1. Relevant information—information that is pertinent or essential to the solution of the problem.

2. Inferential-Experimental Questions.

A-2. Irrelevant questions.
B-2. Inadequate questions.
C-2. Additional questions.
D-2. Relevant questions.

In this manner, a variety of questions is available for the child to ask. He is able to use hypothetical experiments as well as gather pertinent data. After gathering data, the child processes it and if a change has occurred in his outlook toward the problem, he has an opportunity to express this change in Section IV.

IV. After gathering data by pulling the question tabs, the child is asked to explain the problem situation that was presented in the film.

Comparing the written response in Section IV with that of Section II reveals whether the

child has given evidence of having discovered the relationship and has solved the problem.

V. If he has conceptualized from the experience, he should be able to describe a similar problem situation. A transfer type of question is asked involving the same concept in a different context.

This last question is asked to see if the child can transfer the concept of the main problem into another problem situation.

Scoring of TISP

As it has been stated, every time the child wishes to ask a question in Section III of TISP, he has the opportunity to pull the corresponding answer tab. As it is removed, each tab is placed on an attached card. Since each tab is identified by a number, the tabs on the card form a complete sequential record of the information used by the child in the solution of the problem. Changes in the problem-solving behaviors of the subjects of this study were observed in the analysis of the pre- and post-test scores.

A copy of TISP may be obtained upon request from the authors.

Those considered to have been successful in solving the problem were those who:

1. Could not answer Section II of TISP, but did, after pulling tabs, answer Section IV.

2. Answered Section II, but answered it incompletely; then in Section IV, after pulling tabs, presented a more complete answer.

Grouped in the category of those unsuccessful in problem solving were those who:

1. Could not answer the problem question even after pulling tabs.

2. Answered the problem question incompletely in both Sections II and IV.

Validity of TISP

The validity of TISP is best described as construct validity. Cronbach asserted that there are three parts to construct validity. They are:

1. Suggesting what constructs might account for test performance.

2. Deriving a testable hypothesis from the theory surrounding the construct.

3. Carrying out an empirical study to test this hypothesis.[8]

It has been asserted that when a child inquires into a problem situation, he searches, processes data, discovers, verifies, and applies learned concepts. If this is true, then TISP must sample all of these behaviors. Thus the validity of this instrument is, in part, the degree to which the instrument samples these behaviors.

After predicting and attempting to explain in Sections I and II, the child is presented with a list of specific questions with which he is able to search for and process data. He also has an opportunity to verify percepts by asking specific questions. While he is searching, processing data, and verifying, he may discover basic relationships. In Section IV, he is given opportunity to indicate this discovery through a written response. Finally, the child has an opportunity to apply his knowledge in another problem situation in Section V.

If TISP reveals the behavior of a child when he inquires into a problem situation logically, it can be assumed that those children who are the most proficient at inquiry are those who have been involved in inquiry training. Therefore, to test the hypothesis that TISP is a measure of the problem-solving or inquiry behaviors of children, analysis was made of the pre- and post-tests of the students who were involved in inquiry training. From a two-by-two table, as illustrated in Fig. 1, a correlation coefficient can be calculated by using the following formula:

$$\phi = \frac{ad - bc}{[(a + b)\ (d + c)\ (b + d)\ (a + c)]^{1/2}}$$

where phi (ϕ) is a correlation coefficient. The value of ϕ is related to the χ^2 value in the following formula:

$$\chi^2 = N\phi^2$$

where N is the sum of $a + b + c + d$.

	0	1	
1	b	a	$a + b$
0	d	c	$d + c$
	$b + d$	$a + c$	

Fig. 1. Phi coefficient table.

The product moment correlation (ϕ) is 0.229, which, with one degree of freedom, gives a χ^2 value that is greater than the critical value at the 0.05 level of significance. However, for the control group, the correlation (ϕ) was not significant. It may be concluded, then, that TISP does have construct validity.

Reliability of TISP

To insure that the forms of TISP are at the same approximate level of difficulty, the coefficient of equivalence of the forms was calculated. Before the three-week training period, each of the control classes was administered one form of TISP: one class took Form A; the other Form B. Three weeks later, after the inquiry group had gone through a period of inquiry training, the control group was administered the other form. Because the control subjects were not involved in inquiry training, it was assumed that they received no intermediate aid or instruction which would help them in solving the TISP problem. Figure 2 summarizes the results of the statistical analysis of the null hypothesis that the two forms of the test are not equivalent.

Score on Test

	+	−
Form A	9	41
Form B	14	36

$\phi = 0.119 \quad \chi^2 = 1.416 \quad \chi^2(0.05) = 3.84$

Fig. 2 Results of TISP—control group.

From this, it can be seen that it is statistically probable that the two forms of TISP are equivalent.

Findings

Hypothesis 1: There is no relationship between inquiry training and changes in students' problem-solving behaviors as measured by TISP.

TABLE I

McNemar Test Comparing Inquiry and Control Groups on Changes in Students' Problem-Solving Behaviors as Measured by the TISP Test

Group	Control	Trainees
Total in group	50	59
Number showing change in problem solving	17	29
Number showing change to better problem solving	10	21
Number showing change to poorer problem solving	7	8
Number showing no change in problem solving	33	30
χ^2 (observed)	0.24	5.41
χ^2 (0.05 level)	3.84	3.84

Hypothesis 2: There is no relationship between inquiry training and changes in students' concept transfer as measured by TISP.

The McNemar Test for Significance of Changes was used to test these hypotheses.

For Hypothesis 1 (see Table I), the observed value of χ^2 (5.41) is greater than the critical value of χ^2 at the 0.05 level of significance, and it appears that there is a relationship between inquiry training and the changes in problem-solving behaviors of students as measured by TISP.

For Hypothesis 2, since the ϕ value of χ^2 (1.04) is less than the critical value χ^2 at the 0.05 level of significance, it appears that there is no relationship between inquiry training and changes in concept transfer as measured by TISP.

Hypothesis 3: There is no relationship between inquiry training and changes in students' recall of factual science information.

To test this hypothesis, the Mann-Whitney U Test was used. To meet the criteria of the test, the two independent groups (trainees and control) have been drawn from the same population (hetero-

geneously grouped sixth grade classes in one school). Present from the two populations, the null hypothesis is that the trainees and the control group will have the same distribution of scores. By using the *changes* in STEP and *Elementary Science Test* scores, a distribution is established for both groups.

For Hypothesis 3 the probability that both the control group and the trainees would have similar populations of scores (representing changes in students' scores in Form B of the tests as compared to those in Form A) is greater than the critical value (0.05) for both the STEP and *Elementary Science Test*. It appears that there is no relationship between inquiry training and changes in students' recall of science factual knowledge as measured by these instruments.

Hypothesis 4: There is no relationship between tested intelligence and the changes in students' problem-solving behaviors that occur in conjunction with inquiry training.

Hypothesis 5: There is no relationship between chronological age and the changes in students' problem-solving behaviors that occur in conjunction with inquiry training.

Hypothesis 6: There is no relationship between science factual knowledge and the changes in students' problem-solving behaviors that occur in conjunction with inquiry training.

Hypothesis 7: There is no relationship between sex and the changes in students' problem-solving behaviors that occur in conjunction with inquiry training.

To test the above hypotheses, the Fisher Exact Probability Test was used.

The results of the statistical analyses indicated that there is no basis for rejecting Hypotheses 4–7.

Summary and Conclusions

It has been questioned that children could benefit from directed instruction in the strategies of problem solving. The evidence in this study indicates that elementary school children, if they are exposed to guidance which is designed to help them enhance their problem-solving behaviors, do show behavior patterns that are indicative of more effective problem solving.

It is also noted that no relationship appeared between tested intelligence and changes in problem-solving behaviors. Is this a function of the selectivity and size of the sample? Further study needs to be done with a larger group of subjects in a less homogeneously selected situation.

Agreement was lacking as to the relationship of tested intelligence, sex, chronological age or science factual knowledge and changes in problem-solving behavior. When the children who had received inquiry training were compared with those who had not, the evidence did not support the assertion that a child's intelligence, sex, chronological age, or science factual knowledge are significant factors in his benefiting from inquiry training.

The children involved in this study were from a narrow band of chronological age. Further evidence is needed as to whether such differences exist between children of more widely varying chronological age differences. While no differences were observed between changes in problem-solving behaviors of boys and girls, would differences be observed with boys and girls of different ages?

It should be noted that only the data from those students who showed changes in problem-solving behaviors were used in the analysis of the relationship between inquiry training and science factual knowledge. Consideration was not given to those students who showed no change, that is, those students who were successful at the beginning and remained successful or who were unsuccessful at the beginning and remained unsuccessful. What characterizes a child who shows no changes in problem solving even after inquiry training?

Much discussion has been given to the relationship between meaningful concept development and inquiry. The results of this study do not support the assertion that meaningful concept development results from inquiry training. Children who were

successful problem solvers on TISP were not able to apply the concept to a different situation. Why? Is the application of a concept to a different situation an adequate criterion for meaningful concept development? Were these different situations "too different" for the child to see the relationship? Further analysis of TISP needs to be made to insure that this aspect of a child's intellectual development is being appropriately sampled.

TISP was designed to allow the child to express himself in presenting an answer to the problem. No hints were given to him whether he was right or wrong. Would a child be helped in his problem solving if he were rewarded by knowing if his answer were right? Also would this affect his concept transfer?

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In the design of curriculum materials, we should strive for a systematic method in which certain critical factors related to student achievement can be consciously incorporated, according to the author. The teacher might then assume the role of diagnostician.

The Relationship of Three Factors in Printed Materials to Student Achievement

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The curriculum designer, today, is confronted with unique tasks with respect to selection of subject matter. He is asked to keep abreast of changing data and theories within the disciplines and also to identify what content is to be incorporated into the existing program. To accomplish these tasks, he must be knowledgeable about each discipline; but to be constantly conversant with any one discipline, requires continuous study. Bingham[1] has pointed out that nearly everything known now in the sciences was unknown when most adults were in school.

As an educator, the designer is faced also with new evidence in psychology which points to a revised theory of learning—a theory which encourages the introduction of content to students at an earlier age than heretofore thought feasible and that accents the desirability of doing so. Fraser[2] sees the educator, in an attempt to meet the challenge, slowly moving from the learner-centered curriculum toward the discipline-centered curriculum. Optimally, the teacher will soon be helping his students develop newly identified concepts of the disciplines through a process grounded in the emerging psychology.

Scholars, scientists, and teachers are becoming increasingly aware of the shortcomings of continuing our present practices in curriculum revision. These efforts usually take the form of periodically depositing newly found data on the existing foundation. Partly from this concern a theory has developed: under each discipline lies a structure which supports its body of accumulated knowledge. It is the understanding of this structure which lends intellectual power to the student, not the nonsequential fragments currently in the curriculum. Bruner,[3] in summarizing the thoughts of leaders from a number of disciplines, stated:

> Designing curricula in a way that reflects the basic structure of a field of knowledge requires the most fundamental understanding of that field. It is a task that cannot be carried out without the active participation of the ablest scholars and scientists.

The problem of curriculum revision and implementation becomes acute and complex. In turning to the structure of the discipline, there is the probability that much of our present curriculum, often considered trivial, will be replaced. Basic concepts known to and identified by the leaders in the disciplines will supplant existing curriculum content. It would not be unreasonable to state that most of these concepts are either foreign to, or at best only vaguely recognized by, the present classroom teacher. It is beyond reasonable expectation that the general practitioner in the classroom will be at ease in this new arena.

Scholars and scientists, although specialists in their realms, would have a difficult time, indeed, communicating the basic concepts which they have identified to elemen-